

4.11 GEOLOGIC RESOURCES AND HAZARDS

This section describes the physiographic and geologic setting, faults, seismicity, and other geologic considerations and resources in the vicinity of the proposed Cabrillo Port Liquefied Natural Gas (LNG) Deepwater Port (DWP), including associated offshore and onshore pipelines. It also addresses concerns raised during the scoping and comment periods for the October 2004 Draft Environmental Impact Statement (EIS)/Environmental Impact Report (EIR). Representative comments included questions about the proposed Project's impact on shoreline erosion; the risk of tsunamis in the Project area; the effects of liquefaction on the pipelines; whether all known faults had been identified for the Project area; and seismic activity, including a worst-case seismic event, and response provisions such as a spill response. These and other potential ways for geologic hazards to impact the Project and other potential impacts of the Project are discussed in this section, and mitigation is identified as applicable. Effects on geologic resources and mitigation measures from alternatives are also evaluated relative to the Project.

Mineral resources and associated impacts are discussed in Section 4.10, "Energy and Minerals." Additional descriptions of erosion and sediment impacts on the environment, e.g., turbidity, and other mitigation measures to be taken are presented in Section 4.18, "Water Quality and Sediments."

2004 USGS Comments Report

U.S. Representative Lois Capps (California 23rd District) requested that the United States Geological Survey (USGS) provide advice on geologic hazards that should be considered in the review of proposed LNG facilities offshore of Ventura County. The USGS responded with a brief report, included in this document as Appendix J1. The following discussion identifies each of the sections of the USGS report and indicates where each topic is addressed or incorporated into Section 4.11.1, "Environmental Setting and Hazards."

Regional Earthquake History. The area's earthquake history is described in Section 4.11.1.2, "Faults and Seismicity" located later in this section. Active faults and associated earthquakes are identified in Table 4.11-1 (see page 4.11-21) and the nearby historic earthquakes with magnitude greater than 5.5 that are mentioned in this section are identified in Table 4.11-2 (see page 4.11-22) and Figure 4.11-7 (see page 4.11-19) as earthquakes #1, 10, 11, 12, 14, 21, and 23. The earthquake magnitudes listed in Table 4.11-2 are often higher than that cited in the USGS report because multiple sources were used for the table and the highest magnitude found was listed.

Location of Active Nearby Faults and Ground Rupture Hazards. The active faults, including the potential of a magnitude (M) 7.5 earthquake from the Anacapa/Dume Fault are described in Section 4.11.1.2, "Faults and Seismicity." Ground rupture is discussed in Section 4.11.1.3, "Fault Rupture," and under Impact GEO-3 and associated mitigation measures.

Hazards from Shaking. Hazards from shaking caused by earthquakes are discussed in Section 4.11.1.4, "Ground Shaking," and under Impact GEO-4 and associated mitigation measures.

Other Earthquake Hazards – Mass Movement. This section of the report describes engineering foundation stability, ground failure, liquefaction, submarine landslides, turbidity currents, and debris flows. These are discussed in Section 4.11.1.5, "Mass Movement," and under Impact GEO-5 and associated mitigation measures. Liquefaction is addressed in Section 4.11.1.6. The historic submarine landslides cited in the document were not located near the Project, but the hazards would be similar to turbidity currents on the fairly gentle slopes in the Project area.

Tsunamis. Tsunamis are discussed in Section 4.11.1.8, "Tsunamis/Seiche" and under Impact GEO-6.

Additional Studies. The USGS recommends various additional studies; however, as discussed in Section 4.11.1.10, "Additional Geotechnical Reports," a number of studies have been completed, and the lead agencies have already determined that additional site-specific geotechnical studies would be required prior to final Project design.

4.11.1 Environmental Setting and Hazards

This section describes the physiography, geology, and associated geologic hazards in the vicinity of the Project site. The Project and alternatives are situated in both the onshore and offshore part of the Transverse Ranges Physiographic Province and the offshore Peninsular Ranges Physiographic Province of the State of California. The Transverse Ranges are characterized by a predominantly east-west trending system of faults, folds, and mountain ranges. The Peninsular Ranges are characterized by northwest trending ridges and mountain ranges separated by basins and faults.

The proposed Project is situated within the Ventura and Santa Monica Basins. The Ventura Basin is bounded on the north and south by major regional faults. The Santa Ynez Fault forms the northern structural boundary while the Santa Monica Fault system forms the southern structural boundary. The Project pipelines come ashore at Ormond Beach, a relatively wide beach, typical of the Ventura County coastline whose shoreline is relatively flat and slopes in a southwesterly direction at 0.13 to 1.3 percent.

The offshore Project, located in the northeastern part of the Santa Barbara Channel, is on the Hueneme-Mugu Shelf (the offshore extension of the Oxnard Plain), the Hueneme-Mugu Slope, and the Santa Monica Basin (see Figure 4.11-1).

The Hueneme-Mugu Shelf varies in width from less than 0.9 nautical mile (NM) (1.04 mile or 1.67 kilometers [km]), west of the Mugu Submarine Canyon to about 3.5 NM (4 miles or 6.5 km) east of the Hueneme Submarine Canyon. Slopes on the shelf are gentle, less than 0.5 to slightly more than 1 degree, and generally to the southwest (see Figure 4.11-1).

- 1 Insert (1 of 2)
- 2 **Figure 4.11-1 Bathymetric Map of Project Area**

- 1 Insert (2 of 2)
- 2 Figure 4.11-1 Bathymetric Map of Project Area

The Hueneme-Mugu Shelf is dissected by a series of submarine canyons between the Hueneme and Mugu Canyons. These canyons and intervening slopes represent the Hueneme-Mugu Slope. The pipeline route has been planned to follow the more gentle slopes along ridges between steeper canyons. The ridge slope along the proposed route ranges from about 2.5 to 6 degrees. The side slopes into the valleys on either side of the proposed pipeline route are noticeably steeper. Adjacent to the ridge slope, the side slopes of the valleys are about 15 to 20 degrees (see Figure 4.11-1). With the exception of the Hueneme and Mugu Canyons, which cut into the shelf to near the shoreline, the transition between the Hueneme-Mugu Shelf and Hueneme-Mugu Slope generally occurs at an approximately 180- to 200-foot (54.9 to 61 meter [m]) depth.

The base of the canyons opens up to the south into the Santa Monica Basin, where ongoing sediment deposition from the canyons forms the Hueneme Fan. The slope of the Hueneme Fan in the vicinity of the Project ranges from about 3 degrees near milepost (MP) 12 to less than 1 degree near the floating storage and regasification unit (FSRU) location (see Figure 4.11-2).

Onshore, the Project is on the coastal margin of the Oxnard Plain, which occupies the southwest part of the older buried Ventura Basin. The Oxnard Plain is broad and relatively flat, with a southwesterly slope (at approximately 0.2 to 0.3 percent) that rises from the sea level to an elevation of approximately 150 feet (45.7 m) near South Mountain. The Line 225 Pipeline Loop and its alternative are located near the eastern boundary of the Ventura Basin in a tributary valley (the Santa Clarita Valley) that is drained by the Santa Clara River. From MP 0.0 to 2.0 the loop traverses relatively rugged terrain, while the remaining pipeline route is in a relatively flat valley floor.

4.11.1.1 Lithology

Nonmarine fluvial, deltaic and lagoonal, and nearshore marine deposits associated with the prehistoric delta of the Santa Clara River and Calleguas Creek form the surface and near-surface deposits of the Oxnard Plain and offshore shelf areas (Entrix 2003). Only surficial deposits are expected to be encountered in the Project area because the facilities would be located only on the sea floor, the surface, or shallow subsurface. Miocene and younger deposits are described below.

Miocene Rocks

Miocene rocks consist of both sedimentary and igneous rocks. Miocene sedimentary rocks have been divided into lower, middle, and upper sedimentary strata. The lower Miocene strata consist of two formation units: (1) the lower shallow marine sandstones with lesser conglomerates, siltstones, and mudstones of the Vaqueros Formation, and (2) the upper claystones, mudstones, siltstones, and subordinate sandstones of the Rincon Shale. The middle Miocene strata consist of typically siliceous, diatomaceous, tuffaceous, phosphatic, or bituminous laminated shales and are associated with subordinate sandstone, siltstone, chert, dolomite, limestone, and bentonite. The upper Miocene strata consist of diatomaceous mudstone, claystone, siltstone, and sandstone of the Sisquoc Formation. Upper Miocene strata in the Ventura Basin or equivalent age

are known as the Santa Margarita or Modelo Formation. Extrusive and intrusive sequences of basaltic, andesitic, and rhyolitic volcanic rocks of lower to middle Miocene age also occur.

Pliocene Rocks

Pliocene sedimentary rocks consist of interbedded sandstone, siltstone, mudstone, and conglomerate of the Repetto and Pico Formations (each lithologically indistinct from one another). These rocks, which are extremely thick along the axis of the Ventura Basin, have been primary oil producers within the basin.

Pleistocene Deposits

Pleistocene sedimentary deposits in the Ventura Basin-Santa Barbara Channel area consist of Santa Barbara Formation (part Pliocene in age), San Pedro Formation (lower Pleistocene), and unnamed beds of upper Pleistocene age. The Santa Barbara Formation is composed of marine and nonmarine interbedded mudstone, siltstone, sandstone, and conglomerate. The San Pedro Formation in the Oxnard Plain area consists of marine and nonmarine interbedded mudstone, sandstone, siltstone, and conglomerate. Coarser-grained facies of this formation near the top and bottom of the unit have been termed the Hueneme and Fox Canyon aquifers in the Ventura-Oxnard area. The unnamed upper Pleistocene deposits in the Oxnard Plain area consist of marine and nonmarine sand, gravel, clay, and alluvium, which unconformably overlie the San Pedro Formation Holocene Deposits.

Unconsolidated and poorly consolidated Holocene sediments cover the Oxnard Plain and most of the Hueneme-Mugu Shelf and adjacent Oxnard Shelf. These deposits consist of sand, gravel, silt, clay, and mudstone with local concentrations of cobbles and boulders, lenses of carbonaceous material, peat, and shell debris. On the Oxnard and Hueneme-Mugu Shelves, the Holocene deposits generally grade from sand in the nearshore area to silt and clay on the outer shelf or slope (see Figure 4.11-3). The geologic map of the Center Road Pipeline and alternatives show that the facilities will be located on Quaternary alluvium and nonmarine terrace deposits (see Figure 4.11-4). The geologic map for the Line 225 Pipeline Loop route also shows that the pipeline would be on Quaternary alluvium and nonmarine terrace deposits, except for the last 0.5 mile (0.8 km), which would be on Plio-Pleistocene nonmarine rocks (see Figure 4.11-5). From the shoreline to approximately MP 5, the offshore Project pipelines would be on a shallow shelf.

From MP 5 to MP 8.1, the Project pipelines would be on a wide ridge or levee top on the Hueneme-Mugu Slope (see Figure 4.11-2 and Figure 4.11-6) (Fugro West 2004a). At this location, the Project pipelines are expected to rest on a thin layer (perhaps less than 3 feet [0.9 m] thick) of Holocene mud directly overlying lower Pleistocene San Pedro Formation, consisting of marine and terrestrial clay, sand, silt, and small amounts of conglomerates.

- 1 Insert (1 of 2)
- 2 **Figure 4.11-2 Seabed Slope Gradients in Project Area**

Insert (2 of 2)

- 1 Figure 4.11-2 Seabed Slope Gradients in Project Area

(insert 1 of 2)

1 Figure 4.11-3 Offshore Surficial Geology of Project Area

- 1 (insert 2 of 2)
- 2 Figure 4.11-3 Offshore Surficial Geology of Project Area

- 1 Insert (1 of 2)
- 2 **Figure 4.11-4 Geology (Ventura County)**

- 1 Insert (2 of 2)
- 2 Figure 4.11-4 Geology (Ventura County)

- 1 Insert (1 of 2)
- 2 **Figure 4.11-5 Geology Los Angeles County**

- 1 Insert (2 of 2)
- 2 Figure 4.11-5 Geology (Los Angeles County)

- 1 Insert (1 of 2)
- 2 **Figure 4.11-6 Local Offshore Geology Map**

- 1 Insert (2 of 2)
- 2 Figure 4.11-6 Local Offshore Geology Map

Offshore, the Project is within a part of the Santa Monica Basin that is underlain by Hueneme Fan deposits (MP 0 to 14). These deposits largely reflect continued deposition of sediment being transported from the Hueneme-Mugu Shelf through the Hueneme and Mugu Canyons by turbidity currents. Seismic reflection data indicates that this part of the basin is underlain by Holocene and Pleistocene fan deposits, Pleistocene marine and nonmarine interbedded mudstone, siltstone, sandstone associated with the Santa Barbara Formation and San Pedro Formation, and other Pliocene and Miocene strata (Entrix 2003). Based on seafloor sediment samples collected throughout the Project area, Holocene sediment primarily consists of fine silt and clay.

Where the proposed pipeline comes ashore, horizontal directional boring (HDB) would be used for construction. At landfall the formations are described as primarily sand and suitable for employing the HDB method (Fugro West 2005a, 2005b). See Chapter 2, "Description of the Proposed Action," for additional information on the use of HDB in the Project.

At the planned mooring location, the lower fan is nearly flat (with gradients of less than 0.15 degrees) and merges with the smooth and featureless Santa Monica Basin.

4.11.1.2 Faults and Seismicity

Southern California is considered very seismically active. The State of California considers a fault segment historically active if it has generated earthquakes accompanied by surface rupture during historic time, i.e., approximately the last 200 years. A fault that shows evidence of movement within Holocene time (approximately the last 11,000 years) is defined as active. A fault segment is considered potentially active if there is evidence of displacement during Quaternary time or approximately the last two million years (Hart and Bryant 1997).

California State Lands Commission (CSLC) and Minerals Management Service (MMS) reports document the offshore seismic risk in the Santa Barbara Channel (Foxall et al. 1995; Foxall et al. 1996). An offshore seismic hazard evaluation was completed that also included some technical modeling (Fugro West 2004b, 2004c; Honegger 2004). Information from these reports has been incorporated into this document.

Some of the major active or potentially active nearby faults include the Malibu Coast Fault, Anacapa/Dume Fault, Holser Fault, Pitas Point-Ventura Fault, Oak Ridge Fault, Simi-Santa Rosa Fault, San Gabriel Fault, and Santa Cruz Island Fault. Other smaller active or potentially active nearby faults include the Wright Road Fault that the Center Road route may cross, the Ventura Fault, Verdugo Fault, Santa Ynez Fault, Springville Fault, and San Cayetano Fault.

The geology map in Figure 4.11-6 shows the offshore Project pipelines possibly crossing the Anacapa/Dume Fault at approximately MP 11.5. The pipelines would also possibly cross the Malibu Coast Fault at approximately MP 9.5. These faults appear to be related to the Santa Cruz Island Fault. A recent report by the USGS indicates that

the offshore pipelines from Cabrillo Port would cross a major east-west fault system that includes, among others, the Santa Cruz Island Fault, the Anacapa/Dume Fault, and the Malibu Coast Fault. The Anacapa/Dume Fault has the potential for producing the largest earthquakes in the region, up to M 7.5 (USGS 2004). The Bailey Fault (approximately 1 mile [1.6 km] east of MP 5) appears to be an inactive fault, which extends inland from the Mugu Lagoon area. A fault along the axis of Hueneme Canyon (approximately 3 miles [4.8 km] west of MP 2) trends northwest-southeast for about 3 miles (4.8 km); this fault appears to be inactive, displacing strata no younger than Miocene in age. No surface evidence of these faults is known, nor have any recorded earthquakes been attributed to them. Epicenters from historical earthquakes over the last 200 years in the Project area greater than M 5 are shown on Figure 4.11-7.

Table 4.11-1 lists known active and potentially active faults with associated earthquakes within 25 miles (40.2 km) of the Project. Table 4.11-2 lists historical earthquakes greater than M 5.5 with epicenters within 25 miles (40.2 km) of the site and their associated faults (Real et al. 1978; Topozada et al. 2000; Yerkes 1985). In order to include the largest recorded earthquake on the San Andreas fault near the Project area, large earthquakes that were within about 80 miles (129 km) are also listed. These tables and Figures 4.11-6 and 4.11-7 also identify all of the nearby earthquakes and named faults that intersect the Project pipelines that were identified by the USGS in a 2004 study done specifically for this Project (see Appendix J1). The USGS study included faults in the National Seismic Hazard Maps database that are the basis for seismic provisions in the International Building Code. To be included in the National Seismic Hazard Maps database the faults must show evidence of fault slip during the past 1.6 million years as well as an established fault slip or a history of past earthquakes (USGS 2004).

Due to the frequency of earthquakes in the Project region, it should be expected that during the design life of the Project, an earthquake would occur. The USGS has estimated a probability of about 35 percent for an earthquake of M 6.5 or larger within 30 miles (48.3 km) of the offshore floating LNG facilities over the next 30 years. This probability increases to about 60 percent for some of the onshore pipeline locations (USGS 2004). Also, due to its potential to produce a great earthquake (>M 8.0) resulting in large, long-period ground motions in the Project area, the San Andreas Fault is also considered to be of significance. The San Andreas Fault is located as close as 20 miles (32.2 km) to the Line 225 Pipeline Loop segment and about 50 miles (80.5 km) from where the Project pipelines would come ashore.

Since periodic earthquakes accompanied by surface displacement can be expected during the Project life, the effects of strong ground shaking, mass movement, and fault rupture are of primary concern for the safe operations of the proposed pipelines and associated facilities.

- 1 Insert (1 of 2)
- 2 **Figure 4.11-7 Geological Faults and Earthquake Epicenters in the Project Area, 1800 to 1999**

1 Insert (2 of 2)

2 Figure 4.11-7 Geological Faults and Earthquake Epicenters in the Project Area, 1800 to
3 1999

4

Table 4.11-1 Active and Potentially Active Faults and Associated Earthquakes Greater than 4.5 Magnitude within 25 Miles of the Project Site

Date	Name of Associated Fault or Zone	Richter Scale Magnitude	Epicenter from Project
01/10/1857	San Andreas Fault	5.6	23 miles (37 km) NNW from Line 225 Pipeline Loop
04/04/1893	Santa Susana Thrust Zone/Simi	5.5	15 miles (24.1 km) S from Line 225 Pipeline Loop
05/19/1893	Unidentified	5.8	18 miles (29 km) WSW from Center Road Pipeline route
12/14/1912	Offshore fault	5.0	15 miles (24.1 km) SSE from Center Road Pipeline route
02/18/1926	Oak Ridge Fault	5.5	20 miles (32.2 km) NW from Center Road Pipeline route
08/05/1930	Anacapa/Dume Fault	5.2	18 miles (29 km) WNW from Center Road Pipeline route
07/01/1941	Pitas-Point Ventura Fault	5.9	22 miles (35.4 km) WNW from Center Road Pipeline route Alternative 2
08/23/1952	San Andreas Fault	5.0	21 miles (33.8 km) ENE from Line 225 Pipeline Loop
02/09/1971	San Fernando Fault	6.6	6 miles (9.7 km) E from Line 225 Pipeline Loop
02/21/1973	Anacapa/Dume Fault	5.3	11 miles (17.7 km) SSW from Center Road Pipeline route
02/21/1973	Malibu Coast Fault	5.9	9 miles (14.5 km) SSE from Center Road Pipeline route
08/06/1973	Anacapa/Dume Fault	5.0	22 miles (35.4 km) WSW from Center Road Pipeline route
09/04/1981	Santa Cruz-Catalina Escarpment	5.9	14 miles (18 km) S of FPSU
01/17/1994	Northridge Fault	6.7	12 miles (19.3 km) S from Line 225 Pipeline Loop
01/17/1994	Northridge (aftershocks)	6.2	22 miles (35.4 km) ESE from Center Road Pipeline route

Sources: Real et al.1978; Topozada et al. 2000; Yerkes 1985. If magnitudes did not agree, the highest was used.

Table 4.11-2 Recorded Earthquakes Greater than 5.5 Magnitude within 25 Miles (40 km) of the Project or Large Quakes within ~80 Miles (129 km), 1800 to 1999

Map No. ^a	Date	Estimated Magnitude ^b	Quake Name and/or Fault Name	Distance and Direction from Project to Epicenter
1	01/09/1857	7.9	Ft. Tejon/San Andreas Fault	~80 miles (129 km) WNW of Center Rd. and 225 Pipeline Loop (Surface rupture 23 miles (37 km) from Line 225 Pipeline Loop)
2	07/21/1952	7.3	Kern Co. quake, White Wolf Fault	~45 miles (72.4 km) NW of Line 225 Pipeline Loop
3	01/10/1857	5.6	San Andreas Fault	~20 miles (32.2 km) NW of 225 Pipeline Loop
4	09/05/1883	6.3	San Andreas Fault	~40 miles (64.4 km) WNW of Line 225 Pipeline Loop
5	01/01/1821	6.3	Unknown	~45 miles (72.4 km) WNW of Center Rd. Line
6	06/29/1926	5.5	Unknown	~28 miles (45.1 km) from Center Rd. route
7	02/09/1971	6.6	Sylmar Quake, San Fernando Fault	~7 miles (11.3 km) NE of Line 225 Pipeline Loop
8	02/09/1971	5.8	Sylmar aftershock	~7 miles (11.3 km) NE of Line 225 Pipeline Loop
9	02/09/1971	5.8	Sylmar aftershock	~7 miles (11.3 km) NE of Line 225 Pipeline Loop
10	08/13/1978	6.0	Santa Barbara	~33 miles (53.1 km) WNW of Center Rd. route
11	07/01/1941	5.9	Pitas-Point Ventura fault	~25 miles (40.2 km) WNW from Center Rd. route
12	12/08/1812	7.5	San Andreas Fault	~50 miles (80.5 km) E of Line 225 Pipeline Loop
13	01/17/1994	6.0	Northridge aftershock	~10 miles (16.1 km) SW of Line 225 Pipeline Loop
14	06/29/1925	6.8	Santa Barbara Channel	~38 miles (61.1 km) W of landfall
15	02/18/1926	5.5	Oak Ridge Fault	~20 miles (32.2 km) W of Center Rd.
16	04/04/1893	5.8	Santa Suzana Thrust Zone-Simi	~5 miles (8 km) S of Line 225 Pipeline Loop
17	01/17/1994	6.2	Northridge aftershock	~7 miles (11.3 km) SE of Line 225 Pipeline Loop
18	01/17/1994	6.7	Northridge Quake and Fault	~12 miles (19.3 km) S of Line 225 Pipeline Loop
19	12/21/1812	7.1	Santa Barbara Channel	~36 miles (57.9 km) W of offshore pipelines
20	05/19/1893	5.8	Unknown	~12 miles (19.3 km) W of offshore pipelines
21	02/21/1973	5.9	Pt. Mugu, Malibu Coast Fault	~9 miles (14.5 km) E of landfall

Table 4.11-2 Recorded Earthquakes Greater than 5.5 Magnitude within 25 Miles (40 km) of the Project or Large Quakes within ~80 Miles (129 km), 1800 to 1999

Map No. ^a	Date	Estimated Magnitude ^b	Quake Name and/or Fault Name	Distance and Direction from Project to Epicenter
22	09/24/1827	6.0	Anacapa/Dume Fault	~8 miles (12.9 km) E of offshore pipelines
23	03/11/1933	6.4	Long Beach	~60 miles (96.5 km) E of FPSU
24	03/11/1933	5.5	Long Beach aftershock	~60 miles (96.5 km) E of FPSU
25	09/04/1981	5.9	Santa Cruz-Catalina Escarpment	~14 miles (22.5 km) S of FPSU
26	07/11/1855	6.0	Unknown	~30 miles (48.3 km) ESE of Line 225 Pipeline Loop
27	10/01/1987	6.0	Unnamed	~33 miles (53.1 km) ESE of Line 225 Pipeline Loop

Source: Topozada et al. 2000.

Notes: All nearby recorded quakes greater than magnitude 5.5 are listed.

^aRefers to location on Figure 4.11-7.

^bThe Caltech Seismological Laboratory was established in 1932. The location and magnitude of earthquakes prior to 1932 are estimates only.

1 4.11.1.3 Fault Rupture

2 Ground surface displacement, or rupture, caused by an earthquake is a major
3 consideration in the design of pipeline crossings of active faults. The State has mapped
4 known faults in inhabited areas as part of the Alquist-Priolo Earthquake Fault Zoning
5 Act. The known faults extending to or near the ground surface in the onshore Project
6 and alternative areas are relatively well-defined. The Center Road Pipeline and Line
7 225 Pipeline Loop routes appear to cross known active or potentially active faults that
8 are capable of surface rupture, and therefore, fault rupture is a direct concern to the
9 Project. The Center Road Pipeline and its alternatives all cross a mapped Alquist-Priolo
10 fault zone (the Wright Road Fault) between approximately MP 12.1 and MP 13.5. The
11 Wright Road Fault has been mapped as a small fault 2.8 miles (4.7 km) long (William
12 Lettis & Associates 2005).

13 The active San Gabriel Fault, or an associated fault, lies very close to Line 225 Pipeline
14 Loop (see Figure 4.11-5, above). However, the more detailed Alquist-Priolo Fault Zone
15 maps do not show the pipeline crossing the fault but crossing within about 0.5 mile (0.8
16 km) of the San Gabriel Fault. A recent geotechnical evaluation shows the San Gabriel
17 Fault about 0.3 mile (0.48 km) away from the proposed pipeline (William Lettis &
18 Associates 2005). This new geotechnical report also states that the pipeline route
19 crosses the eastern projection of the small potentially active Holser Fault. The Holser
20 Fault is poorly located but there is no apparent evidence of previous surface rupture
21 across the proposed routes and, thus, associated fault offset likely is not a significant
22 hazard to the proposed pipelines (William Lettis & Associates 2005). The Holser Fault
23 is found in subsurface oil well logs in the area.

Offshore, there is no evidence of recent fault rupture along the pipeline routes, but some faults could be considered potentially active and the pipelines would likely cross over buried faults. A recent report indicates greater activity than previously understood (Fisher 2005). For example, the offshore Project route crosses the projected Dume Fault at approximately MP 10.5 and the Malibu Coast Fault at approximately MP 9.5.

4.11.1.4 Ground Shaking

Ground shaking is the earthquake effect that results in the vast majority of damage to manmade and aboveground structures. Ground shaking, however, is not a significant hazard to modern buried gas pipelines. An earthquake performance study was conducted on steel gas transmission and supply lines operated by Southern California Gas Company (SoCalGas) over a 61-year period (1933 through 1994). This study found that post-1945 arc-welded transmission pipelines in good repair have never experienced a break or leak during a southern California earthquake (O'Rourke and Palmer 1996).

Strong shaking from an earthquake can result in landslides and turbidity flows, ground lurching, structural damage, and liquefaction. Strong ground shaking can also set into motion other hazards such as fire; disruption of essential facilities and systems, e.g., water, sewer, gas, electricity, transportation, communications, irrigation, and drainage systems; releases of hazardous materials; and flooding as a result of dam or water tank failure.

An internal California Department of Transportation (CalTrans) report estimated the maximum horizontal acceleration on rock or stiff soil sites that could be produced from the maximum credible earthquake along major active faults. The report indicates that the Project and its alternatives are located in an area with the potential to generate a peak ground acceleration (Pga) between 0.5 and 0.7 times the gravitational acceleration (Entrix 2004).

The California Geological Survey (CGS) has conducted calculations to estimate Pga as a fraction of the acceleration due to gravity (g). Structures can then be designed to withstand these ground motions. The Pga is calculated for firm rock, soft rock, and alluvium (which has the highest ground motion). The CGS states that the calculated Pga value has a 10 percent probability of being exceeded in 50 years. To verify the CalTrans report, three representative locations along the Project route were selected to calculate the estimated maximum ground shaking, and the calculated Pga in alluvium ranged from 0.467 to 0.501 g (CGS 2004). These results compare favorably with the CalTrans report listed above.

4.11.1.5 Mass Movement

Damage to pipelines and other facilities could occur due to mass movement of soil. Mass movement includes landslides, liquefaction, subsidence, sand migration, and turbidity currents. The ground shaking from an earthquake could cause loose sediments found on slopes to move. On shore, seismic hazard zone maps show that

the Center Road Pipeline and alternate routes occur almost entirely within areas that may be subject to liquefaction, but avoid areas that are considered as having landslide potential (CGS 2002; California Division of Mines and Geology [CDMG] 1998b; CDMG 2002). The Line 225 Pipeline Loop encounters areas that are considered as having landslide potential in MP 0 to 3, and over the last 0.5 mile (0.8 km); the areas in between are considered as having liquefaction potential (CDMG 1998a). Off shore, the proposed route is in areas with gentle slopes and avoids active offshore canyons (see Figures 4.11-2 and 4.11-6, above). However, the potential for slides and turbidity currents still exists but is much lower since these areas were avoided.

Turbidity flows or currents are debris flows that occur under water. They are typically triggered by earthquakes or storms. The flows typically consist of a slurry of fine-grained sediments that can travel substantial distances down slope due to gravity. The sediment and current may exert substantial forces on a subsea structure. The Applicant had several studies performed to investigate the potential for turbidity currents, model forces that may be exerted on the pipelines due to the currents, and to make recommendations (Fugro West 2004b, 2004c; Intec 2004b). Three locations, at MP 9.3, 15.5, and 20.5 along the route of the proposed offshore pipelines have been identified as being in the pathway of potential turbidity flows (Fugro West 2004c). Specific increased wall thickness, concrete weighted coating, and final design studies were recommended to make the pipelines more stable and able to withstand the modeled turbidity currents (Intec 2004b).

Natural gas may be present in marine sediments. The presence of gas bubbles in the pore space of sediments can increase pore pressure and reduce the shear strength of the sediment and thus increase the likelihood of mass movement. Under some circumstances, sediment containing dissolved gas can liquefy spontaneously when it is subjected to cyclic loading such as could be caused by earthquake shaking. Based on intermediate- to high-resolution seismic records, gas seeps have not been identified beneath the Project area (Entrix 2003).

4.11.1.6 Liquefaction

Liquefaction is the phenomenon in which saturated granular sediments temporarily lose their shear strength during periods of strong ground shaking, such as that caused by an earthquake. The area considered to have the highest liquefaction potential along the offshore part of the Project is on the shallow shelf near the onshore landing, where the thickest deposits of potentially liquefiable material are expected (Fugro West 2004a).

As described above, most of the onshore pipeline routes are in areas that are considered to have liquefaction potential due to the granular soils and shallow water table. However, liquefaction is not a hazard to properly designed and constructed modern pipelines unless liquefaction is accompanied by lateral (sideways) spreading. Few areas of liquefaction potential in the Project area are at risk of lateral spreading.

4.11.1.7 Subsidence and Settlement

Land surface subsidence can be induced by both natural and human phenomena. Natural phenomena include subsidence from tectonic deformations and seismically induced settlements; soil subsidence due to consolidation, hydrocompaction, or rapid sedimentation; and subsidence due to oxidation of organic-rich (peat) soils. Subsidence or settlement related to human activities includes subsidence caused by a decrease in pore pressure due to the withdrawal of groundwater or petroleum products and the dewatering of organic-rich soils.

There are two types of settlement: compaction and consolidation. Compaction, as herein defined, occurs in dry or moist cohesionless sediments, whereas consolidation occurs in water-saturated sediments. In both types of settlement, vibratory motion causes granular sediments to be rearranged into a denser packing. The net result is reduction of void space, a corresponding reduction of the overall thickness of the cohesionless materials, and possible settlement of the ground surface. If the soil is dry, the settlement (compaction) is concurrent with the earthquake motion. Consolidation is a relatively slow process compared to compaction and is a function of the permeability of the soil.

Seismically induced differential settlement generally occurs in loose, granular soils. Cohesive or clay soils and sediments exhibit little or no settlement as a direct result of ground shaking. Theoretically, little damage to a structure (such as the Project pipeline) would occur if the soil settles uniformly. Totally uniform settlement is rare, however, and differential settlement can cause considerable damage to improperly engineered structures. Results of a 1976 study by Sprotte and Johnson indicate that the potential for seismically induced differential settlement of Holocene sediments in the Project area is high (Entrix 2004).

The most common cause of human-induced subsidence is the withdrawal of fluids, including oil, gas, and water. Subsidence due to groundwater extraction withdrawal is the most extensive type of subsidence in California (City of Oxnard et al. 1980; CDMG 1973). A large area of the Oxnard Plain has experienced subsidence. This area has been monitored by the United States Coast and Geodetic Survey since 1930 and has experienced as much as 0.04 to 0.05 feet (0.01 to 0.02 m) of subsidence per year (City of Oxnard et al. 1980). A single point located at Hueneme Road and State Route 1 dropped 1.5 feet (0.5 m) in 21 years. Records from 1968 show a dozen benchmarks that have settled 1 foot (0.3 m) in a 15- to 20-year period. However, subsidence will probably continue, and the rate and amount could increase if extraction of fluids from the area is maintained at its current level or increases.

No large-scale local subsidence has been reported in the City of Santa Clarita, near the proposed the Line 225 Pipeline Loop, due to groundwater or oil extraction (City of Santa Clarita 1991). Much of the city is located over consolidated sediments that are not very prone to subsidence. Therefore, the subsidence potential associated with groundwater or oil removal within the city is low (City of Santa Clarita 1991).

There is some risk of a change in elevation as a result of vertical movement along the San Gabriel Fault. Although this fault is generally described as being strike-slip, it is common to have localized uplift or downdropping along strike-slip faults. Therefore, it is possible to have some localized, seismically induced subsidence within the Line 225 Pipeline Loop vicinity (City of Santa Clarita 1991). Movement along a strike-slip fault is predominantly parallel to the face of the fault, i.e., the movement is to the side. The predominant movement of a normal or reverse fault is up or down relative to the face of the fault.

4.11.1.8 Tsunamis/Seiche

Tsunamis are sea waves generated by rapid displacement of a large volume of sea water, resulting from submarine vertical faulting or warping of the sea floor, from large-scale submarine slides, or from volcanic eruptions in or near ocean basins. In the open ocean, these waves have a very long period and wavelength, i.e., the waves are spaced far apart and travel at speeds up to hundreds of miles per hour. As a tsunami approaches the shoreline, the speed of the wave decreases and the wave height increases, resulting in potentially destructive effects. Historical records indicate that the severity of tsunami-generated damage varies greatly depending on factors such as coastal topography, the existence of offshore islands, and the direction of the incoming waves.

Although the Pacific Ocean coasts have a long history of tsunami-caused death and destruction, tsunami damage to coastal California has been relatively slight (Entrix 2004). The only tsunami to cause appreciable damage and loss of life along the California coast occurred as a result of the 1964 Alaska earthquake; most of the damage and loss of life occurred along the Northern California coast. Tsunamis have occurred in Southern California about once every 10 years over the last 200 years. The average maximum recorded height of these has been 6.7 feet (2.1 m) (CGS 2005). However, the potential exists for a future major tsunami in the Project area (CSSC 2005). Locally generated tsunamis could result from significant displacement of submarine faults or from submarine slides. An appraisal of the potential for locally generated tsunamis suggests that wave run-up elevations as great as 12 to 18 feet (3.7 to 5.5 m) could be caused by sea-floor faulting in the Santa Barbara Channel (Entrix 2004).¹ According to the Oxnard General Plan, the Center Road Pipeline Route is susceptible to tsunamis between approximately MP 0.0 and MP 1.6 (City of Oxnard 1990).

The CSLC's Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) provide estimated tsunami run-up values for the Ports of Los Angeles, Long Beach, and Hueneme. For the Ports of Los Angeles and Long Beach, the run-up elevation with a 100-year return period is 8.0 feet (2.46 m) and the run-up elevation with a 500-year return period is 15.0 feet (4.6 m) (USGS 2005). For the Port of Hueneme, the run-up

¹ Run-up elevation is defined as a wave's elevation above sea level at the limit of penetration at the shoreline.

elevation with a 100-year return period is 11.0 feet (4.38 m) and the run-up elevation with a 500-year return period is 21.0 feet (6.46 m) (CSLC 2004).

Seiches are oscillations in an enclosed body of water, such as a lake, that may be caused by an earthquake. Most seiches are created when landslides fall into a body of water and displace a large volume of water. There are no enclosed bodies of water in the Project vicinity.

4.11.1.9 Paleontological Resources

Paleontological resources are the mineralized (fossilized) remains of prehistoric plants and animals and the mineralized impressions (trace fossils) left as indirect evidence of the form and activity of such organisms. These resources are considered to be non-renewable resources.

Paleontologic sensitivity is the potential for a geologic unit to produce scientifically significant fossils, as determined by rock or unconsolidated material type, the history of the rock or unconsolidated material unit in producing fossil materials, and fossil sites that are recorded in the unit. A paleontologic sensitivity rating is derived from fossil data from the entire geologic unit, not just from a specific survey area. Offshore areas may be potential sources of paleontological resources; however, they are generally submerged and therefore inaccessible.

A three-fold classification of sensitivity, labeled as high, low, and indeterminate, is used in California and recommended by the Society of Vertebrate Paleontology. The classification is defined as follows:

- *High Sensitivity* – Fossils are currently observed on site, localities are recorded within the study area, and/or the unit has a history of producing numerous significant fossil remains.
- *Low Sensitivity* – Significant fossils are not likely to be found because of random fossil distribution pattern, extreme youth of the rock unit, and/or the method of rock formation, such as alteration by heat and pressure.
- *Indeterminate Sensitivity* – The rock unit either has not been sufficiently studied or lacks good exposures to warrant a definitive rating. This rating is treated initially as having a high sensitivity or potential. After study or monitoring, the unit may be placed in one of the other categories.

The Museum of Paleontology at the University of California at Berkeley conducted a records search to identify known significant paleontological resources in the vicinity of the Center Road Pipeline, Line 225 Pipeline Loop, and alternative pipeline routes. Dr. Patricia Holroyd, a paleontologist representing the museum, reviewed their records and found that only one known fossil locality was present in the vicinity of the Center Road Pipeline and alternative pipeline routes. A single specimen of a proboscidean tibia was found at this location in the late Pleistocene Las Posas Formation (Entrix 2004). One

other mammal specimen in the museum collection was collected in the general area (Camarillo) from the same formation.

Geologic formations of similar age and depositional environment to the Las Posas Formation may be encountered near Beardsley Wash between MP 12.5 and MP 13.8. The remaining parts of the Center Road Pipeline and alternative pipeline routes would be placed at a maximum depth of 7 feet (2.1 m) within recent alluvium (see Figure 4.11-4, above), which has a relatively low probability of containing significant paleontologic resources.

Because the Line 225 Pipeline Loop appears to traverse similar nonmarine sedimentary deposits (Loop MP 0.0 to MP 3) that have been identified as containing paleontological resources along the Center Road Pipeline Route (see Figures 4.11-4 and 4.11-5, above), potentially significant paleontological resources may be present in the materials underlying that part of the Line 225 Pipeline Loop. However, a database search did not reveal any paleontological resources in the vicinity of the Line 225 Pipeline Loop.

4.11.1.10 Additional Geotechnical Reports Prepared by the Applicant

The following geological/seismic hazard reports and preliminary geotechnical studies have been prepared to date by the Applicant for the proposed Project:

- Fugro West. August 2004. Preliminary Seismic and Geologic Hazards Evaluation, Proposed Cabrillo Port Offshore Ventura County, California. Supplement No. 1, Supplemental Description and Evaluation of Turbidity Current Potential.
- Intec Engineering. October 2004. Pipeline Spanning Analysis.
- Intec Engineering. November 2004. Pipeline Stability Under Turbidity Flows.
- D.G. Honegger Consulting. November 5, 2004 Assessment of Potential Seismic Hazards to Cabrillo Port Facilities.
- Fugro West. March 2005. Preliminary Geotechnical Study Summarizing Subsurface Conditions at Southland Sod Farms, Cabrillo Port Pipeline Shoreline Crossing, Ventura County California.
- William Lettis & Associates. April 2005. Geologic and Geotechnical Evaluation of Proposed Center Road and Line 225 Pipeline Loop routes, Ventura and Los Angeles Counties, California.
- Fugro West. June 2005. Geotechnical Desktop Study, Cabrillo Port Pipeline Shoreline Crossing, Ventura County, California (revised).

CSLC engineers and geologists reviewed the geological/seismic hazard reports and preliminary geotechnical studies prepared by the Applicant for the Project and found them to be adequate for the purposes of the environmental review. Further geotechnical studies would be needed, however, for the final design stage after the conclusion of the environmental review. Similarly, the USCG has sufficient information for the purposes of this review.

Neither Federal (the USCG and the U.S. Maritime Administration [MARAD]) nor State (CSLC) lead agencies require deepwater port applicants to provide final detailed designs as part of their application. If an application is approved and MARAD issues a deepwater port license or a license with conditions, the deepwater port licensee is required to submit all plans of the offshore components comprising the deepwater port to the USCG for approval. If the CSLC approves the lease application, the conditions of the lease would include specific requirements for submittal of detailed design criteria and final detailed engineering designs by the Applicant for review and approval by State agencies. Additional studies may be required for final design and would require Federal and State approval before construction of the deepwater port can begin.

4.11.2 Regulatory Setting

The Project would comply with all applicable laws, ordinances, regulations, and standards related to geologic hazards and resources during and following construction (see Table 4.11-3).

4.11.3 Significance Criteria

Significance criteria were determined based on California Environmental Quality Act Guidelines, Appendix G, Environmental Checklist Form. For the purposes of this Revised Draft EIR, geological resources impacts are considered significant if the Project:

- Worsens existing unfavorable geologic conditions;
- Releases toxic or other damaging material into the environment as a result of installation activities such as the release of drilling fluids during horizontal directional drilling (HDD) and HDB;
- Causes a loss of a unique paleontologic resource;
- Exposes people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
 - Rupture of a known earthquake fault,
 - Strong seismic ground shaking,
 - Seismic-related ground failure, including liquefaction;
- Causes severe damage or destruction to one or more Project components as a direct consequence of a geologic event;
- Releases toxic or other damaging material into the environment as a result of a geologic event; or
- Damages a pipeline due to landslide, lateral spreading, subsidence, liquefaction, or collapse as a result of locating the Project on a geologic unit or soil that is unstable or that would become unstable as a result of the Project;

Table 4.11-3 Major Laws, Regulatory Requirements, and Plans for Geologic Resources

Law/Regulation/Plan/Agency	Key Elements and Thresholds; Applicable Permits
Federal	
<p>Hazards Analysis, (30 Code of Federal Regulations [CFR] 250.204 (b)(1)(viii) and CFR 250.1007 (a)(5) and shallow hazards survey (30 CFR 250.204(a)(17) and CFR 250.909)</p> <p>- MMS</p>	<ul style="list-style-type: none"> Requires an analysis of seafloor and subsurface geologic and manmade hazards of all areas considered for oil and gas pipelines. This includes identifying and evaluating conditions that might affect the safety of proposed operations or that might be affected by the proposed operations. This evaluation process depends primarily on interpretation of data obtained from appropriately designed and executed high-resolution geophysical surveys. While the Project is not required to meet most MMS regulations, the Federal government intends to rely on MMS regulations and expertise as much as practicable to ensure application of appropriate, consistent standards: A shallow hazards survey and a geotechnical analysis of foundation soils/sediments underlying the proposed pipeline route must be performed. Outside of State waters, surveying must meet applicable MMS regulations and policy, as far as practicable.
State	
<p>California Seismic Hazards Mapping Act of 1990 (Public Resources Code § 2690 and following as Division 2, Chapter 7.8) and the Seismic Hazards Mapping Regulations (California Code of Regulations [CCR] Title 14, Division 2, Chapter 8, Article 10)</p>	<ul style="list-style-type: none"> Designed to protect the public from the effects of strong ground shaking, liquefaction, landslides, other ground failures, or other hazards caused by earthquakes. The act requires that site-specific geotechnical investigations be conducted identifying the hazard and formulating mitigation measures prior to permitting most developments designed for human occupancy. Special Publication 117, Guidelines for Evaluating and Mitigating Seismic Hazards in California (CDMG 1997), constitutes the guidelines for evaluating seismic hazards other than surface fault rupture and for recommending mitigation measures as required by Public Resources Code § 2695(a).
<p>The California Coastal Act (CCA) of 1976, as amended</p> <p>- <i>California Coastal Commission (CCC)</i></p>	<ul style="list-style-type: none"> Preserves, enhances, and restores coastal resources. Requires protection against loss of life and property from coastal hazards, including geologic hazards.
<p>California State Lands Commission</p>	<ul style="list-style-type: none"> Requires that the pipelines meet current seismic guidelines such as American Lifeline Alliance, July 2001, Guidelines for the Design of Buried Steel Pipe; American Lifeline Alliance, April 2004, Draft Guideline for Assessing the Performance of Oil and Natural Gas Pipeline Systems in Natural Hazard and Human Threat Events; and American Society of Civil Engineers, 1984, Guidelines for the Seismic Design of Oil and Gas Pipeline Systems.
<p>California Public Resources Code § 5097.5 (Stats. 1965, c. 1136, p. 2792)</p>	<ul style="list-style-type: none"> Defines any unauthorized disturbance or removal of fossil sites or remains on public land as a misdemeanor.

Table 4.11-3 Major Laws, Regulatory Requirements, and Plans for Geologic Resources

Law/Regulation/Plan/ Agency	Key Elements and Thresholds; Applicable Permits
Uniform Building Code (UBC) and the California Building Code (CBC)	<ul style="list-style-type: none"> Contains requirements related to excavation, grading, and construction. Applicable codes and industry standards related to various geologic and soil features are identified in Appendix 8-3, Civil Engineering Design Criteria, UBC. The Project site is in the UBC and CBC Seismic Zone 4; the requirements included in the UBC and CBC for Zone 4 shall apply to the Project, including consideration for ground acceleration in structural design to provide earthquake-resistant design. According to the CBC, a grading permit is required if more than 50 cubic yards (38.2 cubic meters [m³]) of soil is moved. Chapter 33 of the CBC contains requirements relevant to the construction of pipelines alongside existing structures. CCR Title 23, §§ 3301.2 and 3301.3, contain the provision requiring protection of the adjacent property during excavations and require 10 days written notice and access agreements with the adjacent property owners. The UBC and CBC do not specifically apply to below-ground gas transmission pipelines operated by public utilities.
Alquist-Priolo Special Studies Zones Act of 1972 (CA Public Resources Code §§ 2621-2630).	<ul style="list-style-type: none"> Requires that "sufficiently active" and "well-defined" earthquake fault zones be delineated by the State geologists. Prohibits locating structures for human occupancy across the trace of an active fault. Does not specifically regulate pipelines, but it does help define areas where fault rupture is most likely to occur.
Local Regulations	
Grading Permits - <i>Local City or County</i> <i>Other</i>	<ul style="list-style-type: none"> Required when more than 50 cubic yards (38.2 m³) of soil is moved. No local regulations or codes are applicable beyond those identified in the UBC Appendix, Chapter 33, related to excavation, grading, and construction.

1 The following significance criteria are not applicable to the Project and are not analyzed
2 further:

- 3 • The Project would not involve inundation by seiches, which are oscillations in an
4 enclosed body of water, or flooding. There are no enclosed bodies of water in
5 the Project area, and the onshore pipelines would be buried and not at risk for
6 flooding;
- 7 • The Project would not cause a loss of a unique geologic feature because the
8 pipeline would be constructed in the shallow soil of a primarily alluvial plain and
9 no blasting would occur that would impact geologic features; and
- 10 • Geologic processes would not adversely impact the Project resulting in corrosion,
11 weathering, or fatigue and causing damage to Project components because the
12 Project would not be under extreme weather conditions where such impacts
13 could occur.

- The Project would not cause a significant increase of erosion during or after construction due to disturbance of sediment or soil. The Project pipelines at the shore crossing would be installed using HDB and would be buried at least 50 feet (15.2 m) below the surface of the beach, far enough below the shoreline to avoid erosion. Further offshore, the pipelines would be located where they would avoid areas of sediment transport or be parallel to the primary transport direction (downslope), to the extent practicable.
- The Project would not damage pipelines and/or pipeline valves from conditions that could release natural gas into the environment and expose people or structures to potential substantial adverse effects because natural gas seeps have not been identified beneath the Project area.

4.11.4 Impact Analysis and Mitigation

Applicant-proposed measures (AM) and agency-recommended mitigation measures (MM) are defined in Section 4.1.5, "Applicant Measures and Mitigation Measures."

Impact GEO-1: Worsens Existing Unfavorable Geologic Conditions and/or Releases Toxic or Other Damaging Material into the Environment

Construction activities could temporarily worsen existing unfavorable geologic conditions (Class II).

During Project construction, the Applicant would use both HDB and HDD. The major difference between these two techniques is that in HDD, the excess drilling fluid and cutting spoils are returned to the drill rig using high pressure to force these materials through the pipe and back through the annular space; as the length of the hole increases, the pressure has to be increased, which increases the possibility of frac-outs (loss of drilling fluid). The HDB method uses a semi-closed loop principle, in which a pump (located near the drill head) collects the excess fluid and cuttings and pumps them back to the drill rig; this allows the process to use lower pressures and minimizes or eliminates the possibility of frac-outs.

In the proposed Project, HDB would be used by the Applicant for the shore crossing – i.e., from a point approximately 344 feet (105 m) inland to a point 3,921 feet (1,195 m) offshore (a total of 4,265 feet [1,300 m]). HDD would be used to install the onshore pipelines (Center Road Pipeline and Line 225 Pipeline Loop) beneath large roadways and railroads, and HDD could be used as an alternate method for crossing the Santa Clara River in Santa Clarita for the Line 225 Pipeline Loop (Cherrington 2006; Brungardt Honomichi 2006). See Chapter 2, "Description of the Proposed Action," for additional information on the use of HDD and HDB in the proposed Project.

Trenching and HDD/HDB activities could increase erosion, differential compaction, or scour, resulting in hazardous conditions for the pipelines. The trenching or drilling could also provide preferential flow paths for fluids in the subsurface. During installation, transitory and sporadic erosion and scour such as during a rainstorm could occur that could expose the onshore pipelines.

The Applicant has incorporated the following measures into the proposed Project:

AM GEO-1a. Drilling Location. For HDB activities at the shore crossing, the Applicant or its designated representative would locate the onshore entry and offshore exit points of the drilling outside of the area affected by normal storms. In addition, the pipeline would be buried deep enough to prevent surfacing due to storm-induced erosion.

AM TerrBio-1a. Erosion Control would apply to this impact (see Section 4.8, “Biological resources – Terrestrial”)

Mitigation Measures for Impact GEO-1: Worsen Existing Unfavorable Geologic Conditions

MM GEO-1b. Backfilling, Compaction, and Grading. Following construction of the onshore pipelines, the Applicant or its designated representative shall properly backfill and compact the right-of-way as defined by standard construction practices, grade the trench to preexisting contours and revegetate/restore the landscape to preexisting conditions to prevent preferential flow paths, erosion, or subsidence.

MM WAT-3a. Drilling Fluid Release Monitoring Plan would apply to this impact (see Section 4.18, “Water Quality and Sediments”).

The mitigation measures cited above would limit the construction effects on unfavorable geologic conditions through adequate planning and design such as proper backfilling and compaction and other standard construction practices, and geologic conditions would be restored to their preexisting conditions. With implementation of these measures, temporary construction impacts that worsen existing unfavorable geologic conditions would be reduced to a level below their significance criteria.

Impact GEO-2: Cause a Loss of a Unique Paleontological Resource

Construction activities could disturb or destroy paleontological resources; such impacts are typically permanent (Class II).

As discussed above, there are several areas along the Center Road Pipeline and Line 225 Pipeline Loop that are tentatively classified as having a high sensitivity for containing significant paleontological resources.

Mitigation Measure for Impact GEO-2: Disturbing or Destroying Paleontological Resources

MM GEO-2a. Inspection. The Applicant or its designated representative shall have a qualified paleontologist complete a paleontological inspection prior to excavating in the suspect areas between Center Road Pipeline MP 12.6 and MP 14.3 in Beardsley Wash, and Line

225 Pipeline Loop from Loop MP 0.0 to MP 3.5 and MP 6.7 and MP 7.7. Paleontological monitoring of excavations in these areas shall be undertaken by a qualified paleontologist based on the findings of the inspection. The paleontologist shall provide education and training for construction workers about potential paleontological resources that may be discovered and, subject to prior approval by the CSLC, he/she shall have the ability to stop construction if potentially significant resources are identified and threatened by the Project. All specimens collected from public land shall be deposited at a curating institute such as the University of California.

Implementation of this mitigation measure would minimize potential impacts on significant paleontological resources through identification and protection of such resources. This impact would be reduced to level below its significance criteria.

Impact GEO-3: Expose People or Structures to Adverse Effects Due to Direct Rupture along Fault Lines, Ground Shaking, or Seismic-related Ground Failure

Damage to pipelines or other facilities could occur due to direct rupture (ground offset) along fault lines (Class II).

An earthquake can cause significant surface displacement along its surface trace. For example, the 1971 San Fernando (Sylmar) quake had a measured offset of up to 6.2 feet (1.9 m), and the 1992 Landers quake, located in the Mojave Desert, had offsets of up to about 19 feet (5.8 m). However, there is no surface (ground) rupture from most earthquakes. Substantial displacement could cause a rupture of a pipeline.

Welded steel pipelines can be designed to withstand substantial fault movement without rupture when the direction, location, and magnitude of the anticipated offset is well defined. However, significant fault rupture (such as occurred in the 1992 Landers or 1906 San Francisco quakes, which had offsets of 19 feet [5.9 m] or more) could result in pipeline rupture even if all protective design measures are implemented. An earthquake performance study was conducted on steel gas transmission and supply lines operated by SoCalGas over a 61-year period (1933 through 1994). This study found that post-1945 arc-welded transmission pipelines in good repair have never experienced a break or leak during a Southern California earthquake (O'Rourke and Palmer 1996). The study included the evaluation of pipelines during 10 earthquakes greater than magnitude 5.8 since 1945 and located near the gas transmission lines. Pipeline breaks did occur but were on older pipe that was not arc-welded.

The CSLC requires the incorporation of current seismological engineering guidelines such as the Guidelines for the Design of Buried Steel Pipe (American Lifeline Alliance), Guidelines for the Seismic Design of Oil and Gas Pipeline Systems (American Society of Civil Engineers), and other recognized industry guidelines for seismic-resistant design at all fault crossings.

The offshore gas pipelines could be adversely affected by seismic activity but would be designed to accommodate, based on the then most current information, anticipated maximum lateral/vertical motion from earthquakes (permanent deformation of seafloor) during the final design stage. If seafloor motion were to exceed allowable stresses in the pipelines, pipelines could rupture and cause a leak. The loss of pressure should induce the safe shut-down of the system, and natural gas would rise to the surface. Offshore, few potential ignition sources exist in the vicinity of the proposed pipelines. Onshore pipelines would be similarly designed to accommodate anticipated displacement by earthquakes and a loss in pressure would activate their shut-down system.

The Applicant has incorporated the following into the proposed Project:

AM GEO-3a. Avoidance. The Applicant would avoid crossing known active fault zones, where possible.

AM GEO-3b. Pipeline Flexibility. Except for the shore crossing, where the pipelines would be installed beneath Ormond Beach, the Applicant would install the offshore pipelines directly on the seabed surface to allow enhanced flexibility (compared with a buried pipeline) and to help them withstand movement caused by fault rupture. Under normal conditions (not due to mass movement) some sediment may cover the pipelines; however, minor sediment should not affect the flexibility of the pipelines. Pipeline routes would also be designed to cross potential faults at as much as a right angle as possible. Offset of pipelines crossing strike-slip or normal faults at right angles induces tension in the pipe, rather than compression. Pipelines can withstand significant offset when in tension.

Mitigation Measures for Impact GEO-3: Damage Due to Direct Rupture along Fault Lines

MM GEO-3c. Geotechnical Studies. The Applicant shall complete final site-specific seismic hazard studies, to be approved by the CSLC and USCG, prior to construction. The studies shall cover suspected active fault crossings to accurately define the fault plane location, orientation, and direction of anticipated offset, and shall include the magnitude of the anticipated offset at the fault locations; this information shall be used to refine fault crossing design parameters. The studies shall take into consideration that it is best to orient the pipe at fault crossings to produce tension in the pipe if there is ground rupture along the fault; compression of the pipe is more likely to cause pipe rupture than tension. The final site investigation report(s) shall contain, at a minimum, the following information:

- A wide-area swath bathymetry program to evaluate turbidity flow pathways from canyons that are outside the immediate project area;
- Additional near-bottom geophysical surveys (side-scan sonar and sub-bottom profiler data);
- Shallow geotechnical borings at each anchor location and pipeline end member location;
- Shallow geotechnical borings at selected locations along the pipeline route to evaluate soil conditions, including the two fault zones;
- Shallow geotechnical borings within canyon sidewalls adjacent to the proposed pipeline route to assess soil conditions relative to slope stability; and
- Shallow geotechnical borings along the HDD path to evaluate soil conditions in the offshore area.

MM GEO-3d. Design and Operational Procedures. The Applicant shall evaluate a larger trench, engineered backfill, thicker wall pipe, shutoff valves placed on either side of fault crossings, and telemetric control for final pipeline design. The Applicant shall use design guidelines in the publications, *Guidelines for the Design of Buried Steel Pipe* and *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems*.

Adherence to these mitigation measures would ensure that the pipeline is adequately planned and designed. Avoiding crossing active faults and improving flexibility by installing pipelines on the ocean floor would reduce potential damage from seismic events. Conducting additional geotechnical studies would provide more refined information for final design. The measures would make pipelines stronger, and digging a larger trench with more backfill would allow greater pipeline flexibility. Installing a shut-off valve would increase safety in case of a pipeline rupture. Table 4.2-2 in Section 4.2, "Public Safety: Hazards and Risk Analysis," identifies the regulatory agencies that would be responsible for reviewing and approving the final design and verifying that the techniques selected for fault crossings would be safe. The Project would avoid known fault crossings except for the small, buried Wright Road Fault (as discussed in Section 4.11.1, "Environmental Setting and Hazards"). These measures would thereby reduce the impact on people and structures to a level below geologic hazard significance criteria.

Impact GEO-4: Cause Severe Damage to Project Components as a Direct Consequence of a Geologic Event, Releasing Toxic or Other Damaging Materials into the Environment.

Ground shaking from earthquakes, which is of a transitory and sporadic nature, could damage Project components (Class II).

The aboveground structures, such as the offshore part of the pipelines or the onshore processing facilities, would be subject to strong ground shaking, and strong earthquake-induced ground shaking could result in significant damage to aboveground structures and lead to failure of open trenches during construction. Ground shaking generally impacts buried modern welded pipelines only when the shaking induces mass movement such as liquefaction, differential settlement, or landslides. Pipe damage also may result from transient ground deformation caused by the peak ground velocity of the seismic wave. However, the O'Rourke and Palmer study found that arc-welded steel transmission pipe is highly resistant to traveling ground waves. The impacts of mass movement are discussed below under Impact GEO-5.

Mitigation Measure GEO-4: Damage to Project Components from a Geologic Event

MM GEO-4a. Design for Ground Shaking. The Applicant shall employ proper seismic design, including but not limited to the design guidelines in the publications Guidelines for the Design of Buried Steel Pipe, Guidelines for the Seismic Design of Oil and Gas Pipeline Systems, and the American Society of Mechanical Engineers' Managing System Integrity of Gas Pipelines.

Adherence to seismic design guidelines would allow pipelines and other structures to withstand intense ground shaking without collapsing or rupturing and would reduce impacts to Project components from ground shaking to a level below their significance criteria.

Impact GEO-5: Damage a Pipeline due to Landslides, Mudflow, Lateral Spreading, Subsidence, Liquefaction, or Collapse as a Result of Locating the Project on a Geologic Unit or Soil that is Unstable

Mass movement, which is of a transitory and sporadic nature, could damage pipelines or structures (Class III).

Ground shaking or other processes may cause mass movement. During loss of ground bearing capacity, such as with liquefaction, large deformations can occur within the soil mass, allowing structures to settle or tilt. A large enough movement could cause pipeline rupture. Liquefaction of a buried layer may result in substantial lateral spreading of overlying competent soil. A good example of lateral spreading occurred during the 1971 San Fernando (Sylmar) earthquake, when an area of almost 163 acres (66 hectares) moved down a 2.5 percent slope. In addition, lateral spreading was responsible for most of the water pipeline failures in San Francisco during the 1989 Loma Prieta earthquake.

The offshore pipeline routes have been selected to take advantage of gentle slopes and areas that are more stable. The Hueneme-Mugu Shelf in the vicinity of the Project is considered stable, based on the low-angle slopes of about 0.3 to 0.4 percent and the lack of direct evidence of previous instability. Evidence of submarine slides has been recorded in the general vicinity of the Project along the Hueneme-Mugu Slope and within the associated submarine canyons. Also, the Hueneme and Mugu Canyons are considered active sediment transport areas, transporting sediment from the nearshore shelf to the basin floor via turbidity flows. The proposed Project route does not overlie areas with previously identified slump movement or canyons where turbidity flows are most likely to occur, but the route is along a slope that is susceptible to creep. However, the Applicant has identified three areas where the marine pipeline could be subject to turbidity flows, and thicker wall pipe, concrete weighted coating, and final design studies have been recommended for these areas (Fugro West 2004c; Intec 2004b). The area considered to have the highest liquefaction potential along the offshore part of the Project is on the shallow shelf near the onshore landing. It is in that location that the thickest deposits of potentially liquefiable material are expected. The maximum depth of liquefaction is anticipated to be around 22 to 32 feet (6.7 to 9.8 m) (Fugro West 2004b).

Most of the onshore parts of the pipelines are in areas that are considered to have liquefaction potential due to the granular soils and shallow water table. However, the route does have gentle slopes. Some of the Line 225 Pipeline Loop route is in areas with landslide potential; however, the proposed route does not cross any identified active or recently active landslides (William Lettis & Associates 2005).

The Applicant has incorporated the following measure into the proposed Project:

AM GEO-5a. Avoid Areas of Mass Movement. To the extent possible, the Applicant would avoid areas of soil susceptible to mass movement and areas of steeper slopes (for example, where the proposed Line 225 Pipeline Route crosses at the Santa Clara River and San Francisquito Creek, where mass movement may be more likely). The pipeline would be attached to existing bridges to avoid mass movement along the stream banks and would be designed with a thicker wall pipe to withstand potential pressures due to mass movement and to allow flexibility should movement occur.

Mitigation Measure GEO-5: Damage to a Pipeline as a Result of Locating the Project on a Geologic Unit or Soil that is Unstable

MM GEO-3c. Geotechnical Studies would apply to this impact.

Completion of final site-specific seismic hazard studies, approved by the CSLC and USCG prior to construction, would ensure that suspected active fault crossings are accurately defined so that proper design parameters are implemented. In addition, the Applicant would be required to design and construct the pipelines and facilities in accordance with all applicable standards and regulations. These measures, along with

applicable standards and regulations, would ensure that impacts resulting from damage to a pipeline as a result of Project location would be below geological hazard significance criteria.

Impact GEO-6: Damage to Pipelines from Tsunamis

Tsunamis, which are transitory and sporadic in nature, could damage nearshore pipelines or facilities due to the typical force and erosive nature of these storms (Class III).

There is little risk of damage from tsunamis to facilities located in deep water, such as the proposed location of the FSRU, but significant erosion, high current, and wave forces could occur in shallow water near the shore. This impact is considered adverse but not significant due to the depth of burial of the pipeline at the shore crossing; however, potential tsunamis could damage the Ormond Beach Metering Station.

The Applicant has incorporated the following into the proposed Project:

AM GEO-6a. Pipeline Burial. The pipeline at the shore crossing would be buried at least 50 feet (15.2 m) below the surface of the beach and deeply enough below sea level to minimize the potential of frac-outs. This will also avoid potential damage from tsunamis.

Impacts and mitigation measures associated with geological resources are summarized in Table 4.11-4.

Table 4.11-4 Summary of Geologic Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
Impact GEO-1. Construction activities could temporarily worsen existing unfavorable geologic conditions (Class II).	<p>AM GEO-1a. Drilling Location. The Applicant or its representative would locate the onshore entry and offshore exit points for HDB the drilling at the shore crossing outside of the area affected by normal storms. In addition, the pipeline would be buried deep enough to prevent surfacing due to storm erosion.</p> <p>AM TerrBio-1a. Erosion Control.</p> <p>MM GEO-1b. Backfilling, Compaction, and Grading. Following construction of the onshore pipelines, the Applicant or its designated representative shall implement proper backfilling and compaction, as defined by standard construction practices, and grade the trench to preexisting contours and revegetate/restore the landscape to preexisting conditions to prevent preferential flow paths, erosion, or subsidence.</p> <p>MM WAT-3a. Drilling Fluid Release Monitoring Plan (see Section 4.18, "Water Quality and Sediments").</p>

Table 4.11-4 Summary of Geologic Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
Impact GEO-2. Construction activities could disturb or destroy paleontological resources; such impacts are typically permanent (Class II).	MM GEO-2a. Inspection. The Applicant or its designated representative shall have a qualified paleontologist complete a paleontological inspection prior to excavating in the suspect areas.
Impact GEO-3. Damage to pipelines or other facilities could occur due to direct rupture (ground offset) along fault lines (Class II).	<p>AM GEO-3a. Avoidance. The Applicant would avoid crossing known active fault zones, where possible.</p> <p>AM GEO-3b. Pipeline Flexibility. Except for the shore crossing, where the pipelines would be installed beneath Ormond Beach, the Applicant would install the offshore pipelines directly on the seabed surface to allow enhanced flexibility (compared with a buried pipeline) and to help them withstand movement caused by fault rupture. Under normal conditions (not due to mass movement) some sediment may cover the pipelines; however, minor sediment should not affect the flexibility of the pipelines. Pipeline routes would also be designed to cross potential faults at as much as a right angle as possible. Offset of pipelines crossing strike-slip or normal faults at right angles induces tension in the pipe, rather than compression. Pipelines can withstand significant offset when in tension.</p> <p>MM GEO-3c. Geotechnical Studies. The Applicant shall complete final site-specific seismic hazard studies, to be approved by the CSLC and USCG, prior to construction.</p> <p>MM GEO-3d. Design and Operational Procedures. The Applicant shall evaluate larger trench, engineered backfill, thicker wall pipe, shutoff valves placed on either side of fault crossings, and telemetric control for final pipeline design.</p>
Impact GEO-4. Ground shaking from earthquakes, which is of a transitory and sporadic nature, could damage Project components (Class II).	MM GEO-4a. Design for Ground Shaking. The Applicant shall employ proper seismic design, including but not limited to the design guidelines in the publications Guidelines for the Design of Buried Steel Pipe, Guidelines for the Seismic Design of Oil and Gas Pipeline Systems, and the American Society of Mechanical Engineers' Managing System Integrity of Gas Pipelines.
Impact GEO-5. Mass movement, which is of a transitory and sporadic nature, could damage pipelines or structures (Class III).	<p>AM GEO-5a. Avoid Areas of Mass Movement. To the extent possible, the Applicant would avoid areas of soil susceptible to mass movement and areas of steeper slopes.</p> <p>MM GEO-3c. Geotechnical Studies.</p>

Table 4.11-4 Summary of Geologic Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
Impact GEO-6. Tsunamis, which are transitory and sporadic in nature, could damage nearshore pipelines or facilities due to the typical force and erosive nature of these storms (Class III).	AM GEO-6a. Pipeline Burial. The pipeline at the shore crossing would be buried at least 50 feet (15.2 m) below the surface of the beach and deeply enough below sea level to minimize the potential of frac outs. This will also avoid potential damage from tsunamis.

4.11.5 Alternatives

4.11.5.1 No Action Alternative

As explained in greater detail in Section 3.4.1, "No Action Alternative," under the No Action Alternative, MARAD would deny the license for the Cabrillo Port Project and/or the CSLC would deny the application for the proposed lease of State tide and submerged lands for a pipeline right-of-way. The No Action Alternative means that the Project would not go forward and the FSRU, associated subsea pipelines, and onshore pipelines and related facilities would not be installed. Accordingly, none of the potential environmental impacts identified for the construction and operation of the proposed Project would occur.

Since the proposed Project is privately funded, it is unknown whether the Applicant would fund another energy project in California; however, should the No Action Alternative be selected, the energy needs identified in Section 1.2, "Project Purpose, Need and Objectives," would likely be addressed through other means, such as through other LNG or natural gas-related pipeline projects. Such proposed projects may result in potential environmental impacts of the nature and magnitude of the proposed Project as well as impacts particular to their respective configurations and operations; however, such impacts cannot be predicted with any certainty at this time.

4.11.5.2 Alternative Deepwater Port Location – Santa Barbara Channel/Mandalay Shore Crossing/Gonzales Road Pipeline

The Santa Barbara Channel/Mandalay Shore Crossing/Gonzales Road pipeline alternative would be subject to regional and local geologic hazards similar to those at the proposed Project location, including ground shaking, mass movement and erosion, liquefaction, tsunamis, and shallow gas seeps. The chance of damage from direct fault rupture in offshore areas may be somewhat less than the proposed pipeline location because it is farther from the fault line; however, the alternative location is nearer the estimated location of the epicenters of the large 1812 and 1925 Santa Barbara earthquakes. This alternative would have essentially the same impacts and impact classes as the proposed pipeline route, and the same mitigation measures would apply.

4.11.5.3 Alternative Onshore Pipeline Routes

Center Road Pipeline Alternative 1

The Center Road Pipeline Alternative 1 is farther from the mapped Springville Fault, which is a mapped fault of the Alquist-Priolo Act, and is less likely to cross this fault. All other geologic impacts/hazards, including paleontological resources, ground shaking, liquefaction, and increased erosion, would be essentially the same as for the proposed route. Impact classes would be identical and the same mitigation measures would apply.

Center Road Pipeline Alternative 2

Generally, geologic impacts associated with this alternative would be similar to those of the proposed route, and impact classes would be the same. The Center Road Pipeline Alternative 2 would be closer to the Springville Fault and more likely to cross this fault. All other impacts/hazards, including paleontological resources, ground shaking, liquefaction, and increased erosion, would be essentially the same as for the proposed route and the same mitigation measures would apply.

Center Road Pipeline Alternative 3

Geologic impacts associated with this alternative would be similar to those of the proposed route, and impact classes would be the same. All impacts/hazards, including paleontological resources, ground shaking, liquefaction, and increased erosion, would be essentially the same as for the proposed route and the same mitigation measures would apply.

Line 225 Pipeline Loop Alternative

The Line 225 Pipeline Loop Alternative route would be subject to nearly identical regional and local geologic hazards as the proposed Line 225 Pipeline Loop route, including paleontological resources, seismic hazards, liquefaction, and increased erosion. The HDD river crossing alternative would be subject to a greater chance of erosion and frac-outs than the proposed route. Impacts and classes are the same as those identified for the proposed route, and the same Applicant measures and mitigation measures would apply.

4.11.5.4 Alternative Shore Crossings and Pipeline Connection Routes

Point Mugu Shore Crossing/Casper Road Pipeline

The geologic impacts from the Point Mugu Shore Crossing/Casper Road Pipeline Alternative, including paleontological resources, seismic hazards, threat from tsunamis, liquefaction, and increased erosion, would be essentially the same as those identified for the proposed route. Impacts and classes would be the same as those identified for the proposed route and the same mitigation measures would apply.

Arnold Road Shore Crossing/Arnold Road Pipeline

The geologic impacts from the Arnold Road Shore Crossing/Arnold Road Pipeline Alternative, including paleontological resources, seismic hazards, threat from tsunamis, liquefaction, and increased erosion, are essentially the same as those identified for the proposed route. Impacts and classes are the same as those identified for the proposed route and the same mitigation measures would apply.

4.11.6 References

- Brungardt Honomichl & Company, P.A. 2006. Drilling Fluid Release Monitoring Plan, Horizontal Directional Boring, BHP Document No. WCLNG-BHP-DEO-TX-00-001-0, February 20.
- California Division of Mines and Geology (CDMG). 1973. Urban Geology Master Plan for California. California Division of Mines and Geology. Bulletin 198.
- _____. 1997. Guidelines for Evaluating and Mitigating Seismic Hazards in California. Special Publication 117.
- _____. 1998a. Seismic Hazard Zones, Newhall Quadrangle. February 1.
- _____. 1998b. Seismic Hazard Zones, Santa Paula Quadrangle. May 1.
- _____. 2002. Seismic Hazard Zones, Camarillo Quadrangle. February 7.
- California Geological Survey (CGS). 2002. Seismic Hazard Zones, Oxnard Quadrangle. December 20.
- _____. 2004. Ground Motions for User Selected Site, Probabilistic Seismic Hazards Mapping Ground Motion Page. Accessed April 8.
www.consrv.ca.gov/cgs/rghm/pshamap/pshamap.asp?Longitude=-118.97&Latitude=34.164
- _____. 2005. About Tsunamis. Accessed September 9.
http://www.consrv.ca.gov/cgs/geologic_hazards/Tsunami/About_Tsunamis.htm.
- California Seismic Safety Commission (CSSC). 2005. The Tsunami Threat to California. Findings and Recommendations on Tsunami Hazards And Risks.
- California State Lands Commission. 2004. Marine Oil Terminal Engineering Maintenance Standards (MOTEMS).
- Cherrington Corp. 2006. Preliminary Construction Procedure and Design for Horizontally Bored Pipeline Landfall, BHP Document No.: WCLNG-BHP-DEO-TP-00-0001-0. February 16.

- 1 City of Oxnard. 1990. City of Oxnard 2020 General Plan. November. Includes
2 Amendments through December 2000.
- 3 City of Oxnard, United States Geological Survey, Dames & Moore. 1980.
4 Environmental Impact Report/Environmental Assessment, Union Oil Company, Platform
5 Gina and Platform Gilda Project, Lease OCS P-0202 and OCS P-0216, Offshore
6 Ventura County, California. Volume II. May.
- 7 City of Santa Clarita. 1991. City of Santa Clarita General Plan, Safety Element. Santa
8 Clarita, California.
- 9 Entrix, Inc. 2003. Environmental Analysis, Cabrillo Port Deepwater Port in the Vicinity
10 of Ventura, California. August.
- 11 _____. 2004. Environmental Analysis, Onshore Component of BHP Billiton LNG
12 International Inc. Cabrillo Port Project. May.
- 13 Fisher, Michael A. et al. 2005. Recent Deformation along the Offshore Malibu Coast,
14 Dume, and Related Faults West of Point Dume, Southern California, Bull. Seism. Soc.
15 Am. Vol. 95, No. 6, 2486-2500. December.
- 16 Foxall, William, Auguste Boissonnade, Lawrence Hutchings and Jean Savy. 1995.
17 Technical Issues Relevant to Seismic Hazard of the Eastern Santa Barbara Channel,
18 Lawrence Livermore National Laboratory, Livermore, California (Unclassified). April.
- 19 Foxall, William and Jean Savy. 1996. Probabilistic Seismic Hazard Analysis for
20 Offshore Structures in the Santa Barbara Channel, Phase 2 Report, Lawrence
21 Livermore National Laboratory, Livermore, California (Unclassified). December.
- 22 Fugro West, Inc. 2004a. Pipeline and Anchorage Area Survey, Cabrillo Deepwater
23 Port, Offshore Ventura County, California. Report prepared for BHP Billiton LNG
24 International Inc. March.
- 25 _____. 2004b. Preliminary Seismic and Geologic Hazards Evaluation, Proposed
26 Cabrillo Port Offshore Ventura County, California. Report prepared for BHP Billiton
27 LNG international Inc. June. (Appendix J2 of this report.)
- 28 _____. 2004c. Preliminary Seismic and Geologic Hazards Evaluation, Proposed
29 Cabrillo Port Offshore Ventura County, California. Supplement No. 1, Supplemental
30 Description and Evaluation of Turbidity Current Potential. August.
- 31 _____. 2005a. Preliminary Geotechnical Study Summarizing Subsurface
32 Conditions at Southland Sod Farms, Cabrillo Port Pipeline Shoreline Crossing, Ventura
33 County, California. Report prepared for BHP Billiton LNG International Inc. March.
- 34 _____. 2005b. Geotechnical Desktop Study, Cabrillo Port Pipeline Shoreline
35 Crossing, Ventura County, California. Report prepared for BHP Billiton LNG
36 International Inc. June (Revised) (Appendix J4 of this report.)

- 1 Hart, E.W. and W.A. Bryant. 1997. Fault-Rupture Hazard Zones in California. Special
2 Publication 42. Sacramento, CA.
- 3 Honegger, D.G. 2004. Assessment of Potential Seismic Hazards to Cabrillo Port
4 Facilities, Final Report. Report prepared for BHP Billiton LNG International Inc.
5 November 5.
- 6 Intec Engineering. 2004a. Pipeline Spanning Analysis. October.
- 7 _____. 2004b. Pipeline Stability Under Turbidity Flows. Report prepared for BHP
8 Billiton LNG international Inc. November.
- 9 O'Rourke, T.D. and M.C. Palmer. 1996. Earthquake Performance of Gas Transmission
10 Pipelines. Earthquake Spectra. Vol. 12, No. 3, pp. 493-527.
- 11 Real, et al. 1978. Earthquake Epicenter Map of California, showing events from 1900
12 through 1974 equal to or greater than magnitude 4.0 or intensity V. California Division
13 of Mines and Geology, Map Sheet 39.
- 14 Topozada, et al. 2000. Epicenters of and Areas Damaged by $M \geq 5$ California
15 Earthquakes, 1800-1999. California Division of Mines and Geology, Map Sheet 49.
- 16 United States Geological Survey. 2004. Comments on Potential Geologic and Seismic
17 Hazards Affecting Coastal Ventura County, California. Open-File Report 2004-1286
18 (Appendix J1 of this report.)
- 19 United States Geological Survey (USGS), Western Coastal and Marine Geology,
20 Tsunamis and Earthquakes. Webpage updated February 14 2005, accessed on August
21 3, 2005. <http://walrus.wr.usgs.gov/tsunami/srilanka05/measurements.html>.
- 22 William Lettis & Associates, Inc. 2005. Geologic and Geotechnical Evaluation of
23 Proposed BHP and Line 225 Loop Pipeline Routes, Ventura and Los Angeles Counties,
24 California. Report prepared for Southern California Gas Company. May. (Appendix J3
25 of this report.)
- 26 Yerkes, R.F. 1985. Geologic and Seismologic Setting. In Ziony, J.I. (ed.). Evaluating
27 Earthquake Hazards in the Los Angeles Region – An Earth-Science Perspective.
28 (U.S.G.S. Professional Paper 1360.) p. 25-41.